ENERGY IMPACTS

OVERVIEW: Energy consumption, either during the manufacture of a chemical or the use of a product, process, or technology can vary with a selected chemical or process change. The Energy Impacts module describes methods for evaluating the energy impacts of the baseline and substitutes within a use cluster. In a CTSA, data on the energy impacts of the baseline and substitutes are usually collected in the Performance Assessment module.

GOALS:

- Determine the energy requirements of the baseline and of the substitutes.
- Evaluate the relative energy impacts of the baseline as compared to the substitutes.
- Provide data on energy requirements and relative energy impacts to the Cost Analysis and Risk, Competitiveness & Conservation Data Summary modules.

PEOPLE SKILLS: The following lists the types of skills or knowledge that are needed to complete this module.

- Familiarity with sources and rates of energy consumption (e.g., equipment) in the use cluster.
- Ability to perform simple energy calculations involving power ratings (kW or BTU/hr), duty (hr/day), and equipment load (percent of rated power used during equipment operation).

Within a business or DfE project team, the people who might supply these skills include a plant engineer, environmental engineer, line supervisor, line operator, or equipment vendors.

DEFINITION OF TERMS:

British Thermal Unit (BTU): The quantity of heat required to raise the temperature of one pound of water from 60 to 61 ^{o}F at a constant pressure of one atmosphere.

Duty: Period of time equipment is operated under powered conditions (e.g., lights may be utilized for 16 hrs/day).

Horsepower (hp): The predominant English unit of power used to describe motor ratings in the U.S. In the metric system the usual measure of power is Joules/hr. One hp = 42.43 BTU/min = 2.7×10^6 Joules/hr = 0.7457 kilowatts (kW).

Kilowatt Hour (kWh): One kWh is the quantity of energy converted or consumed in 1 hour at the constant power rate of 1 kW. One kWh is equivalent to 3413 BTU.

Load: A factor reflecting the actual power used by a piece of equipment relative to the design power rating. For example, an electric motor may be oversized and draw only 80 percent of its nominal power rating when operating a specific piece of equipment.

Nominal Power Rating: The nominal energy use rate of energy consuming equipment operating under design conditions (e.g., an electric motor may have a power rating of 1 hp).

APPROACH/METHODOLOGY: The following presents a summary of the technical approach or methodology for evaluating the energy impacts of substitutes. Methodology details for Steps 3, 4, and 6 follow this section.

Step 1: Review the Chemistry of Use & Process Description module to identify pieces of equipment that consume energy in the baseline or the substitutes. Note equipment that would be added or deleted, depending on the substitute. Examples of specific pieces of equipment which consume energy include drive motors, air fans, direct resistance heating elements, refrigeration system compressors, and natural gas-fired ovens.

Step 2: Review the Control Technologies Assessment module to identify the control technologies that are recommended or required for the baseline or the substitutes. This can include air pollution control technologies, chemical destruction technologies (e.g., incineration, etc.) as well as in-plant waste water treatment technologies. The energy consumption of control technologies should also be evaluated, particularly if a control technology is required to meet environmental regulations.

Step 3: Based on the equipment identified in Steps 1 and 2, determine the data required to evaluate the rates of energy consumption of the baseline and of the substitutes. Provide data requirements to the Performance Assessment module so that energy consumption data can be collected during the performance demonstration project. For each piece of energy using equipment, typical data requirements include:

- The nominal power rating.
- The average duty.
- The average load.
- Production capacity/through-put (e.g., parts/hr, ft^2 processed/day).

Data should be collected on a per unit production basis, or some other basis that allows a comparative evaluation of the energy trade-off issues.

Step 4: Obtain data from the Performance Assessment module and calculate the energy requirements of the baseline and of the substitutes. Again, energy requirements should be calculated on a common basis to allow for a comparative evaluation of the substitutes.

Step 5: Provide the energy requirements for the baseline and the substitutes to the Cost Analysis module. The cost of energy usages can be obtained from supplier (e.g., electric utility, natural gas utility) rate schedules.

Step 6: If up-stream energy impacts are being evaluated in the CTSA, review the Chemical Manufacturing & Product Formulation module to evaluate energy requirements during the manufacturing of chemical ingredients or the formulation of chemical products. CTSA pilot projects have qualitatively evaluated up-stream energy impacts.

Step 7: Tabulate energy requirements calculated in Step 4 together with data on up-stream energy impacts from Step 6 to evaluate the relative energy impacts of the baseline as compared to the substitutes.

Step 8: Report the relative energy impacts of the substitutes to the Cost Analysis and Risk, Competitiveness & Conservation Data Summary modules.

METHODOLOGY DETAILS: This section presents methodology details for completing Steps 3, 4, and 6. If necessary, additional information on this and other steps can be found in previously published guidance.

Details: Step 3, Collecting Data on Energy Consumption

Data for each substitute should be collected for a consistent unit process, such as the time to complete the function defined by the use cluster one time. This facilitates a comparative evaluation of the substitutes. The following summarizes sources of nominal power rating, duty, and load data:

- The nominal power rating is usually displayed on an identification plate on the equipment (e.g., a pump motor nameplate may read 1.0 hp). In some cases where nameplate data are unavailable, power ratings may be obtained from the manufacturer's literature or from equipment vendors.
- Duty can be measured using a simple timer or estimated by the equipment operator. Again, duty should be measured for a consistent process (e.g., the time a pump is required to dispense a solvent when cleaning ten 3,200 in^2 printing screens).
- Electric load can be calculated from the average current amperage and the supply voltage (e.g., average current amperage multiplied by supply voltage yields average electric power in kW). The average current amperage can be measured with an electric current (amp) meter. Gas use can be measured with gas metering equipment or it can be estimated by knowledgeable plant personnel.

If performance data are being collected from existing sources instead of tests performed as part of the CTSA, estimates of energy usage data can be obtained from equipment vendors or other sources.

Details: Step 4, Calculating Energy Requirements

Depending upon the particular circumstances, the method for calculating energy use will vary. For example, if each piece of energy consuming equipment in a process is unique and the required data can be readily collected (for example, with a dedicated power meter), the electrical energy consumption rate can be estimated using the following formula:

Net Energy Consumption (energy use/time)
= (No. pieces of equipment) x (power rating/unit) x (average duty) x (load)

Example: A coolant system for a machining operation requires 2 pumps to supply the operation with coolant liquid. The characteristics and operating parameters of each pump are as follows:

pump power rating	= 10 hp
average duty	= 8 hours/day
estimated operating load	= 80 percent

Thus, the estimated net energy consumption for the coolant pumping operation is calculated as:

Net Energy Consumption (kWh/day)
= (2 pumps) x (10 hp/pump) x (1 kW/0.746 hp) x (8 hours/day) x (0.80)
= 172 kWh/day

For equipment using natural gas, the net energy consumption may be given by:

Net Energy Consumption (BTU/day)
= (rating in BTU/hr) x (hours/day duty) x (load)

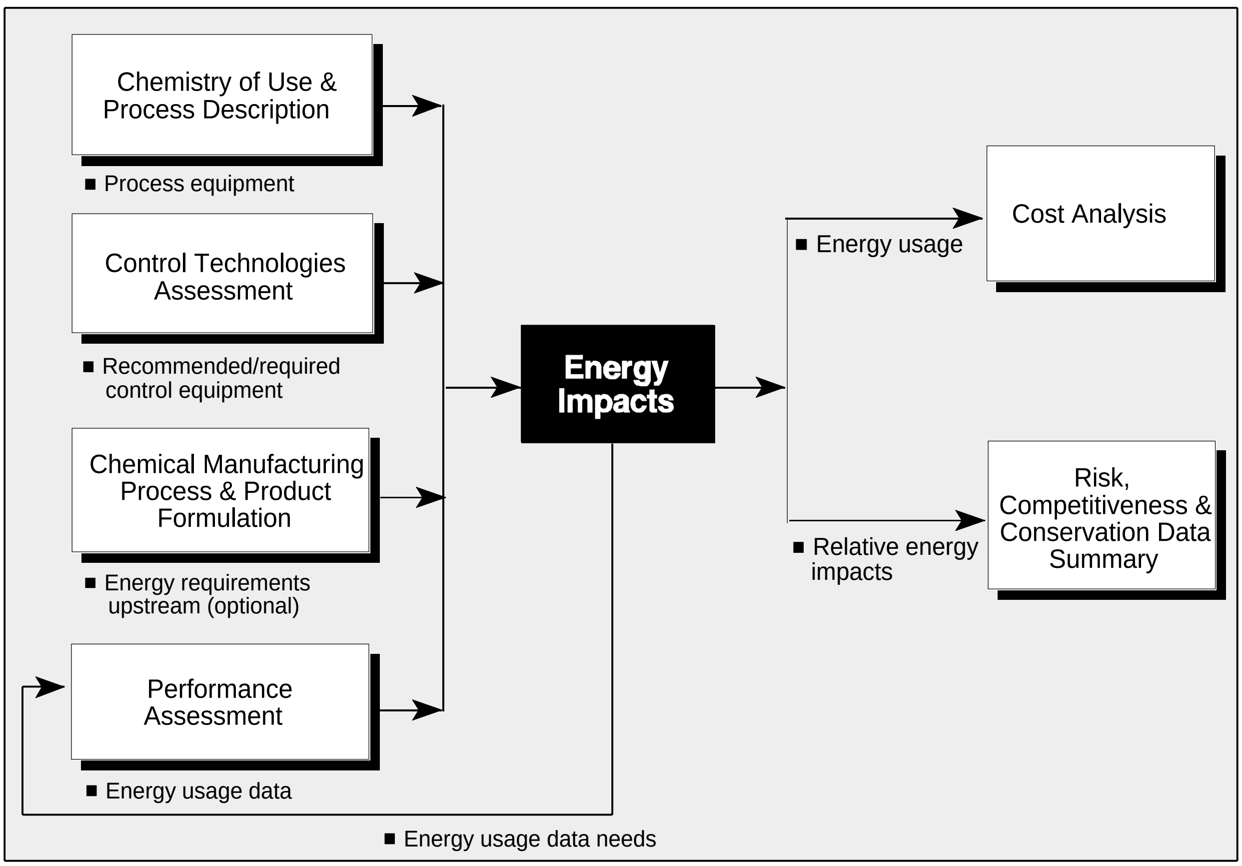
Details: Step 6, Evaluating Up-stream Energy Impacts

The following are examples of the types of questions a DfE project team might consider when qualitatively evaluating up-stream energy impacts:

- Are chemical ingredients made from raw materials that have an energy equivalence (e.g., petroleum-based chemicals versus vegetable-based)?
- Under what types of reactor conditions are chemical ingredients manufactured (e.g., what is the reactor temperature, pressure, and retention time)?
- Is the chemical formulation a simple mixing process? Does it involve chemical reactions between the formulation ingredients? Are heat or pressure required to get chemical ingredients into solution?

FLOW OF INFORMATION: Data requirements for the Energy Impacts module are identified based on information from the Chemistry of Use & Process Description, Control Technologies Assessment, and Chemical Manufacturing Process & Product Formulation modules and collected in the Performance Assessment module. (The energy impacts of up-stream processes, such as chemical manufacturing or product formulation, could be collected from suppliers during a performance demonstration project. Up-stream energy impacts have not been quantitatively evaluated in DfE pilot projects, however.) The Energy Impacts module transfers data to the Cost Analysis and Risk, Competitiveness & Conservation Data Summary modules. Example information flows are shown in Figure 8-1.

FIGURE 8-1: ENERGY IMPACTS MODULE: EXAMPLE INFORMATION FLOWS



ANALYTICAL MODELS: None cited.

PUBLISHED GUIDANCE: Table 8-1 presents references for published guidance on estimating energy consumption for process equipment and performing energy audits.

TABLE 8-1: PUBLISHED GUIDANCE ON ENERGY ASSESSMENTS	
Reference	**Type of Guidance**
Smith, Craig B. 1981. *Energy Management Principles, Applications, Benefits, and Savings.*	Methods for performing energy audits and calculating energy consumption for process equipment.
Thumann, Albert. 1979. *Handbook of Energy Audits.*	Methods for performing energy audits and calculating energy consumption for process equipment.

Note: References are listed in shortened format, with complete references given in the reference list following Chapter 10.

DATA SOURCES: Table 8-2 lists sources of energy consuming equipment data.

TABLE 8-2: SOURCES OF ENERGY CONSUMPTION DATA	
Reference	**Type of Data**
American Council for an Energy-Efficient Economy. 1991. *Energy-Efficient Motor Systems.*	Methods for determining energy consumption and efficiency for various types of electric motors.
Garay, Paul N. 1989. *Pump Application Desk Book.*	Methods for determining energy consumption and efficiency for various liquid pumping systems.

Note: References are listed in shortened format, with complete references given in the reference list following Chapter 10.